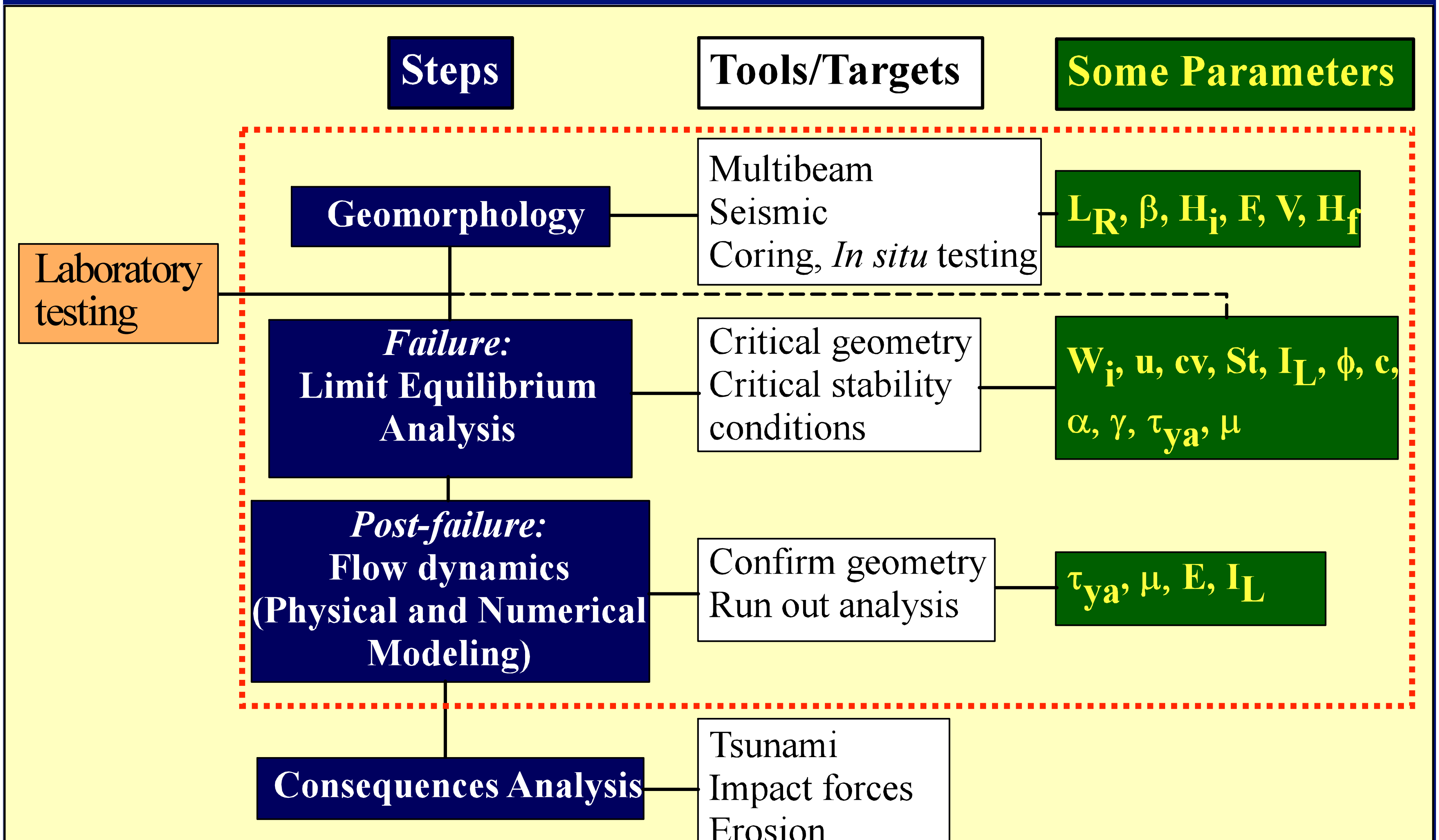
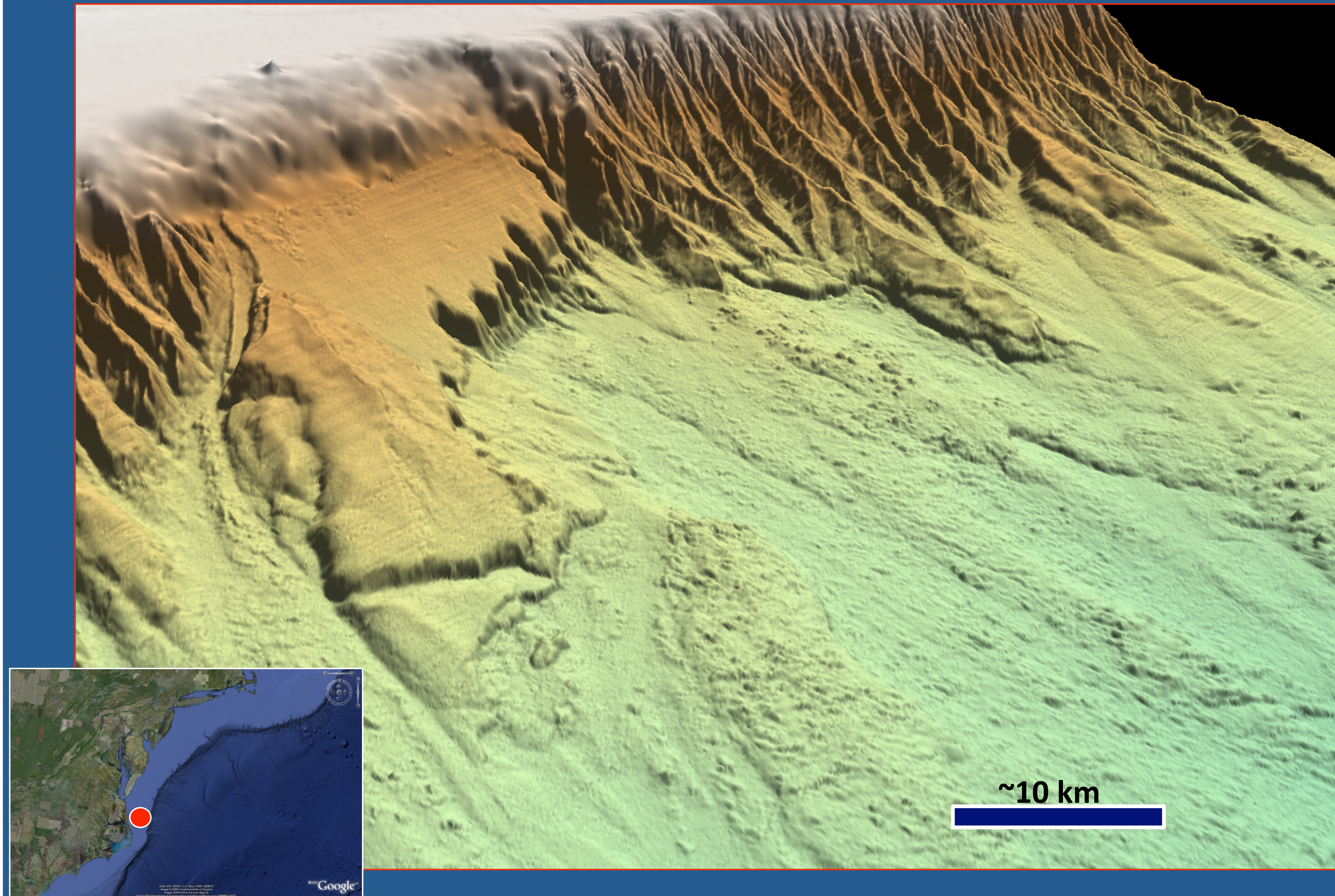
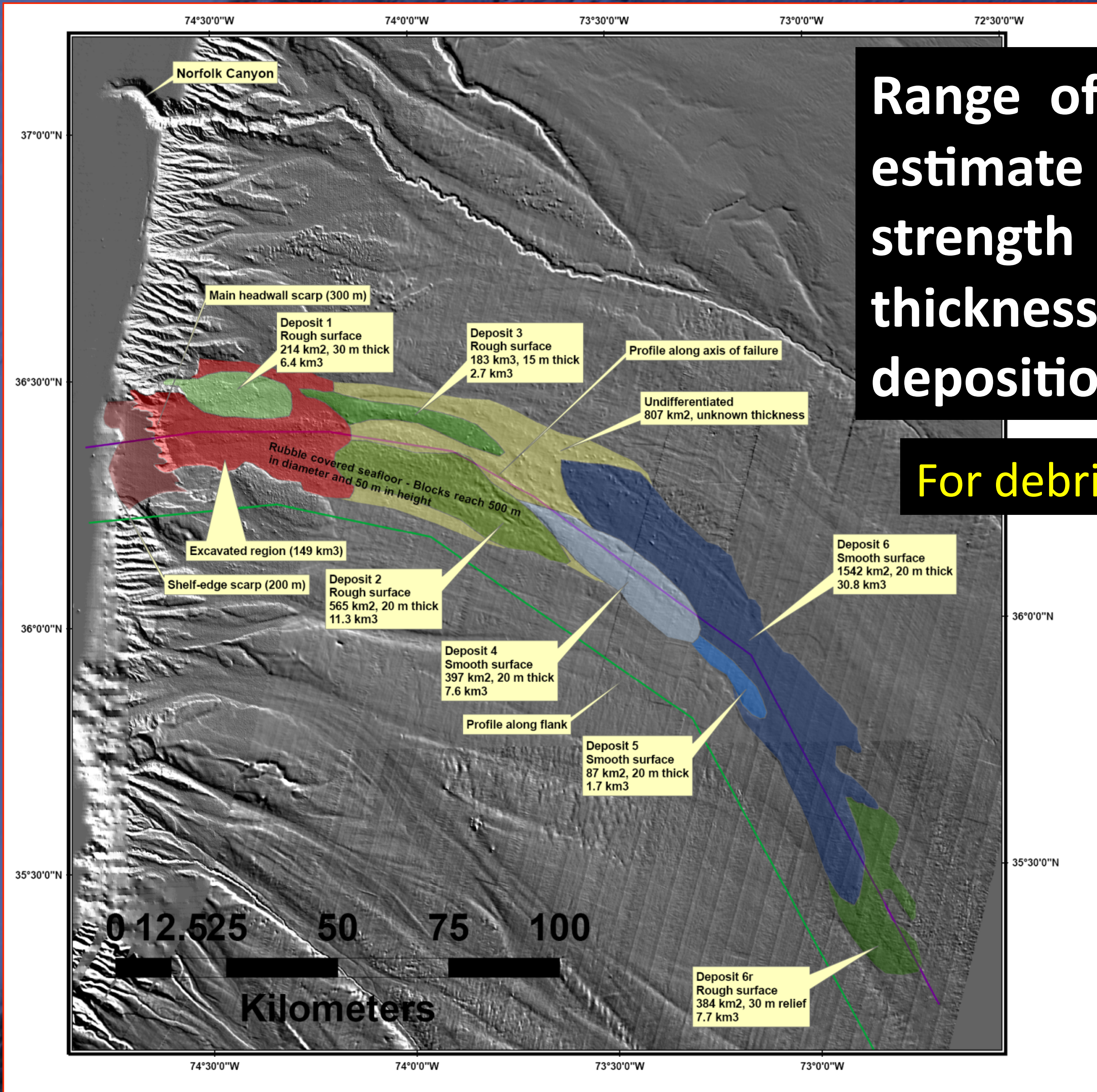
An overal approach linking mobility and tsunami potential used for the Palos Verdes area (California)



Locat and Lee 2005

Example: The Currituck Slide (165 km^3)





Range of data used to estimate the yield strength based on thickness in the depositional zone

For debris, thickness: ~20m

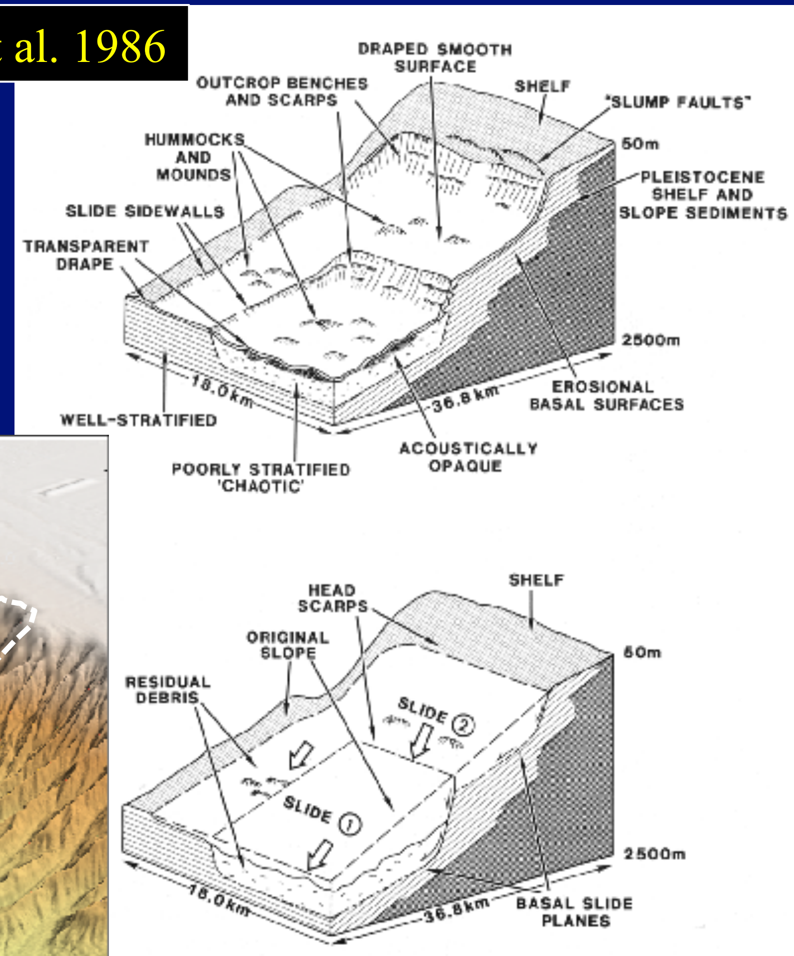
Curritck slide
On Google!

Source: D Twitchel

Pointeur 36°17'58.23" N 72°59'50.96" O élév. 0 m
Mise au point 100%

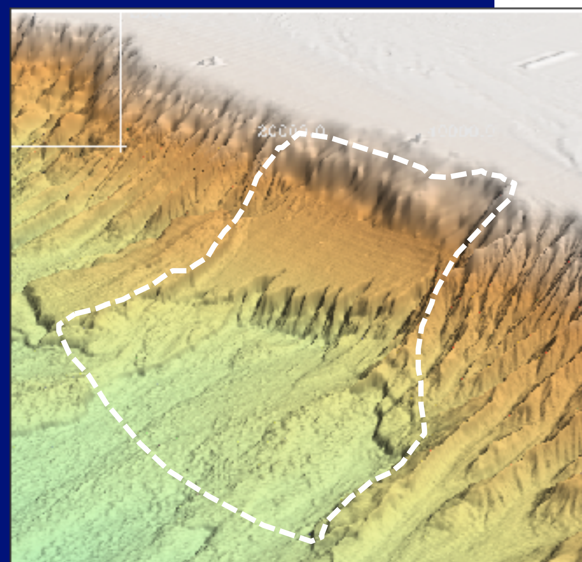
Geomorphology and seismic to reconstruct slide sequences

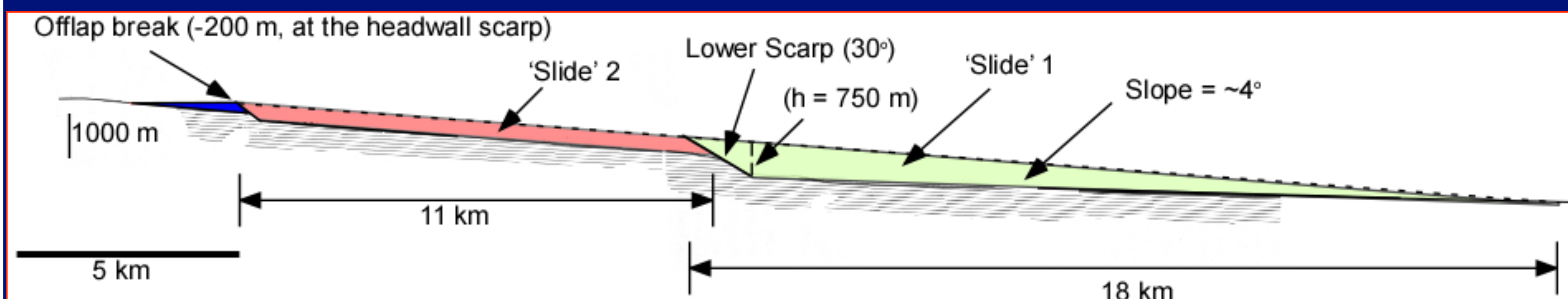
Prior et al. 1986



Slide Volumes

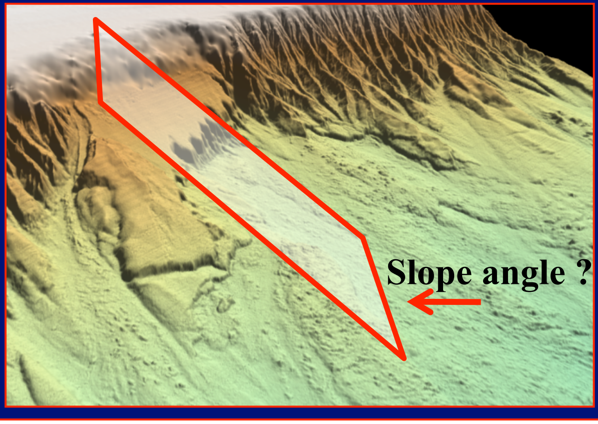
Slide	Prior et al. 1986	Locat et al. 2009
1	78	108
2	46	57
Total	**124**	**165**



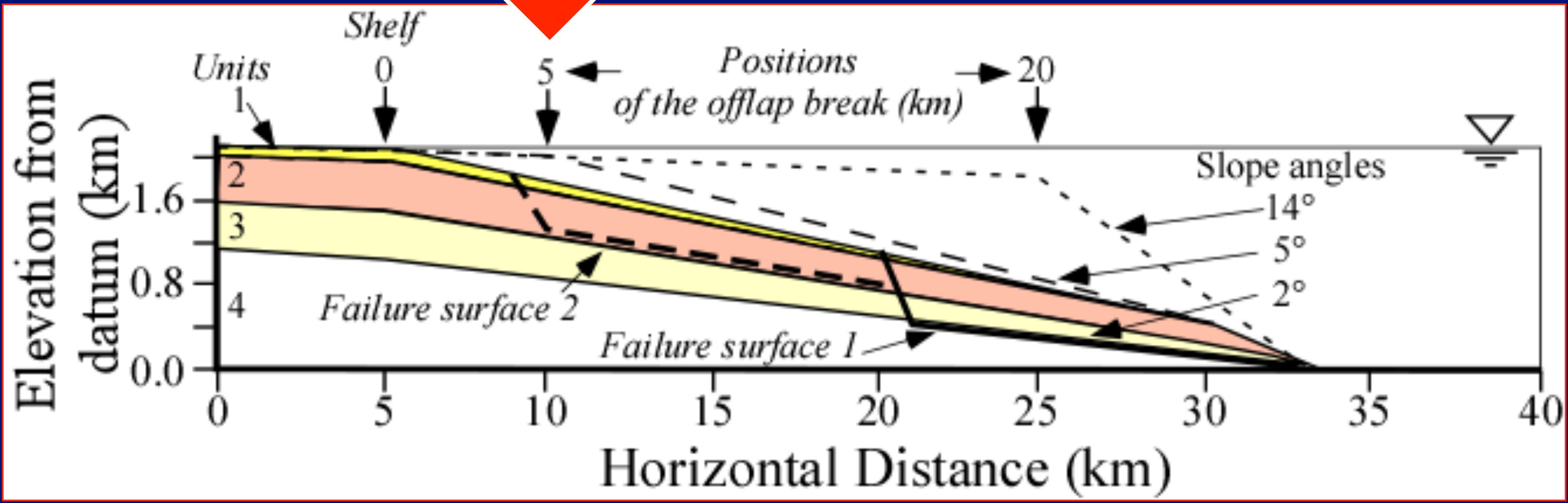


What could be a reasonable geometry for back analysis of the conditions prior to failure ?

As one would expect if failure mechanism is a slab-like failure, very high pore pressure (e.g. r_u of 0.8) or very strong earthquake are need to generate instability



Max for known volume

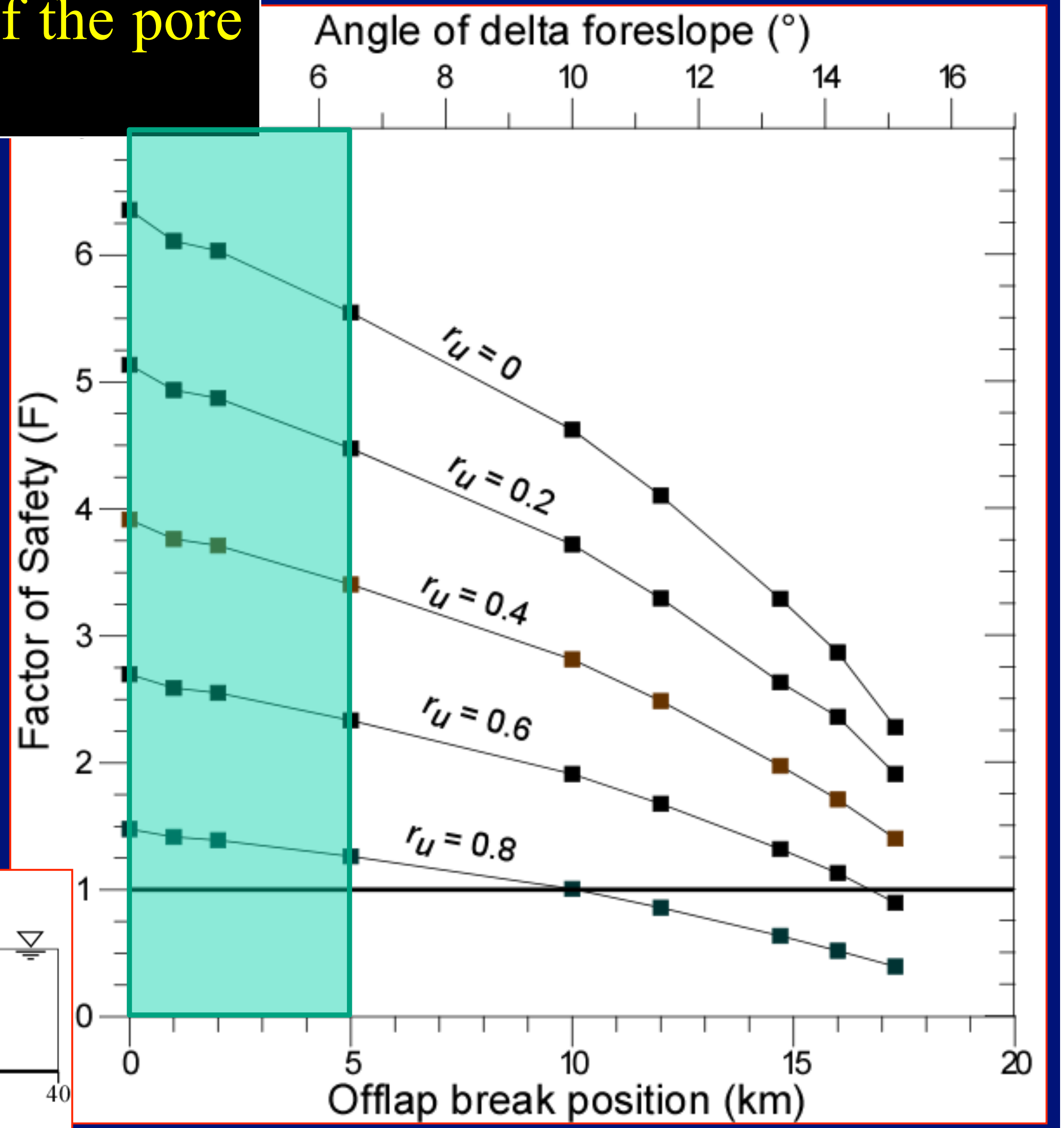


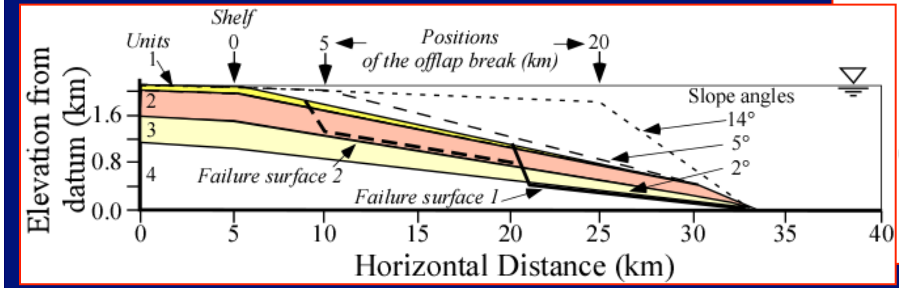
Stratigraphic units and failure surfaces used for slide 1 and 2, and the hypothetical deltaic infill for a delta edge located at 0, 5 and 20 km from actual shelf break position assuming a fix position of the base of the foreslope. (vertical scale exaggeration is 3.75).

Effects of offlap break position (and resulting delta foreslope angle) on the factor of safety as a function of the pore pressure ratio (r_u)

Range of acceptable values to keep the volume of the slide within known limits

Note: r_u values for F=1 are likely too high and one may need to use a more sophisticated slope stability model!

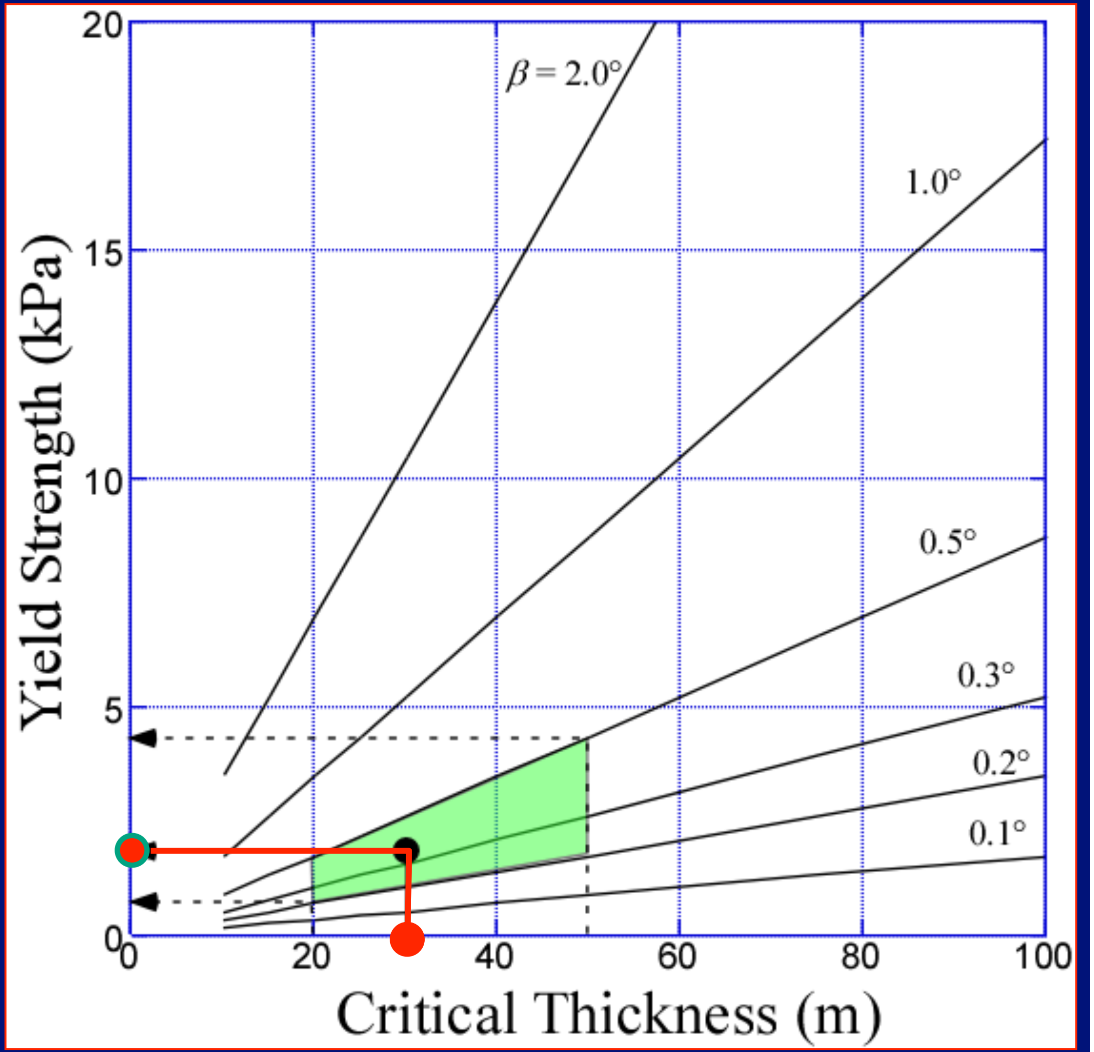




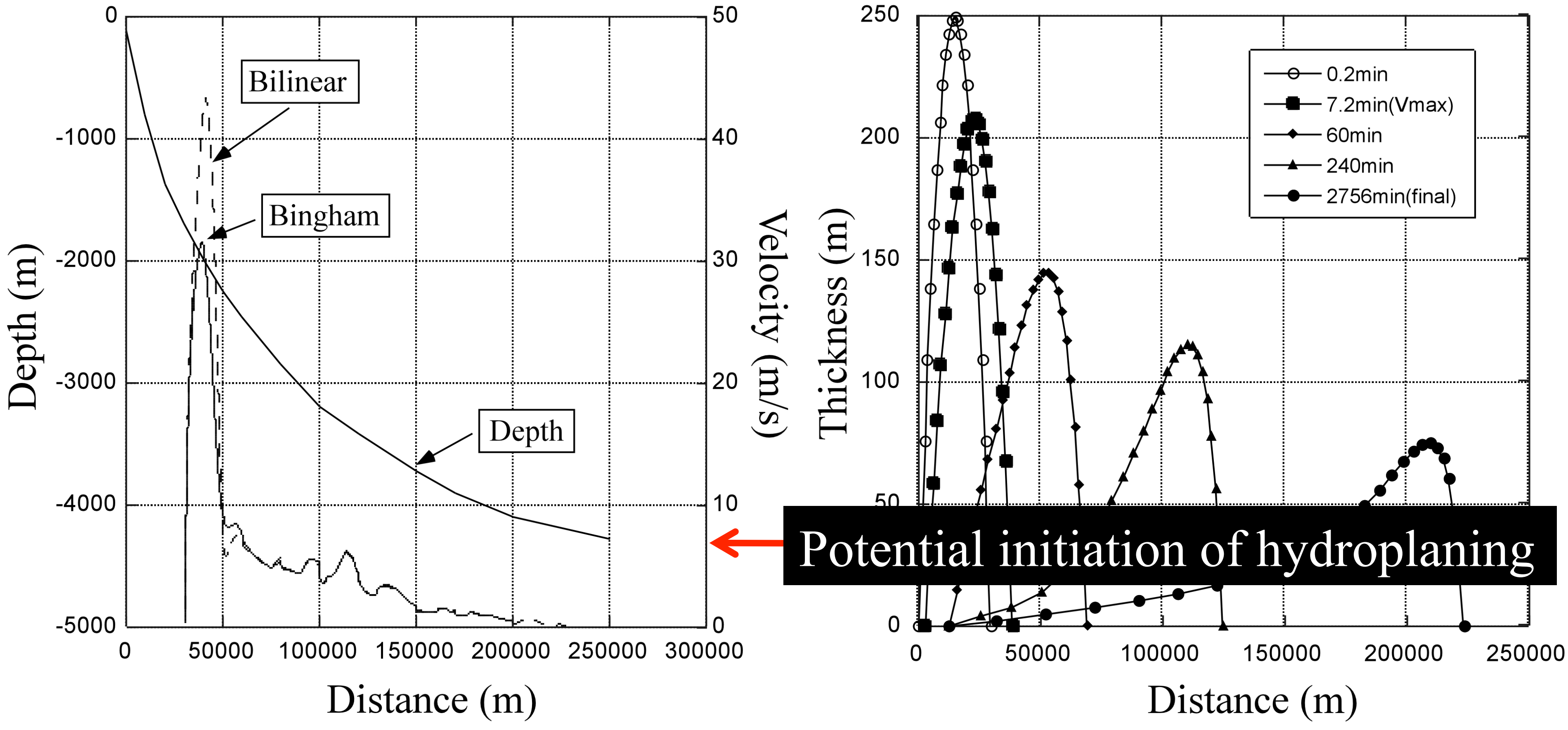
Gemorphology of the debris flow deposit and yield strength

Yield strength as a function of the critical height in the depositional zone. The colored box is for a range of reported thickness for the various depositional lobes. Black dot is for a height of 30 m and a yield strength of 2.0 kPa.

$t_y = H_c\,(g'\,\sin b)$



Currituck mobility analysis

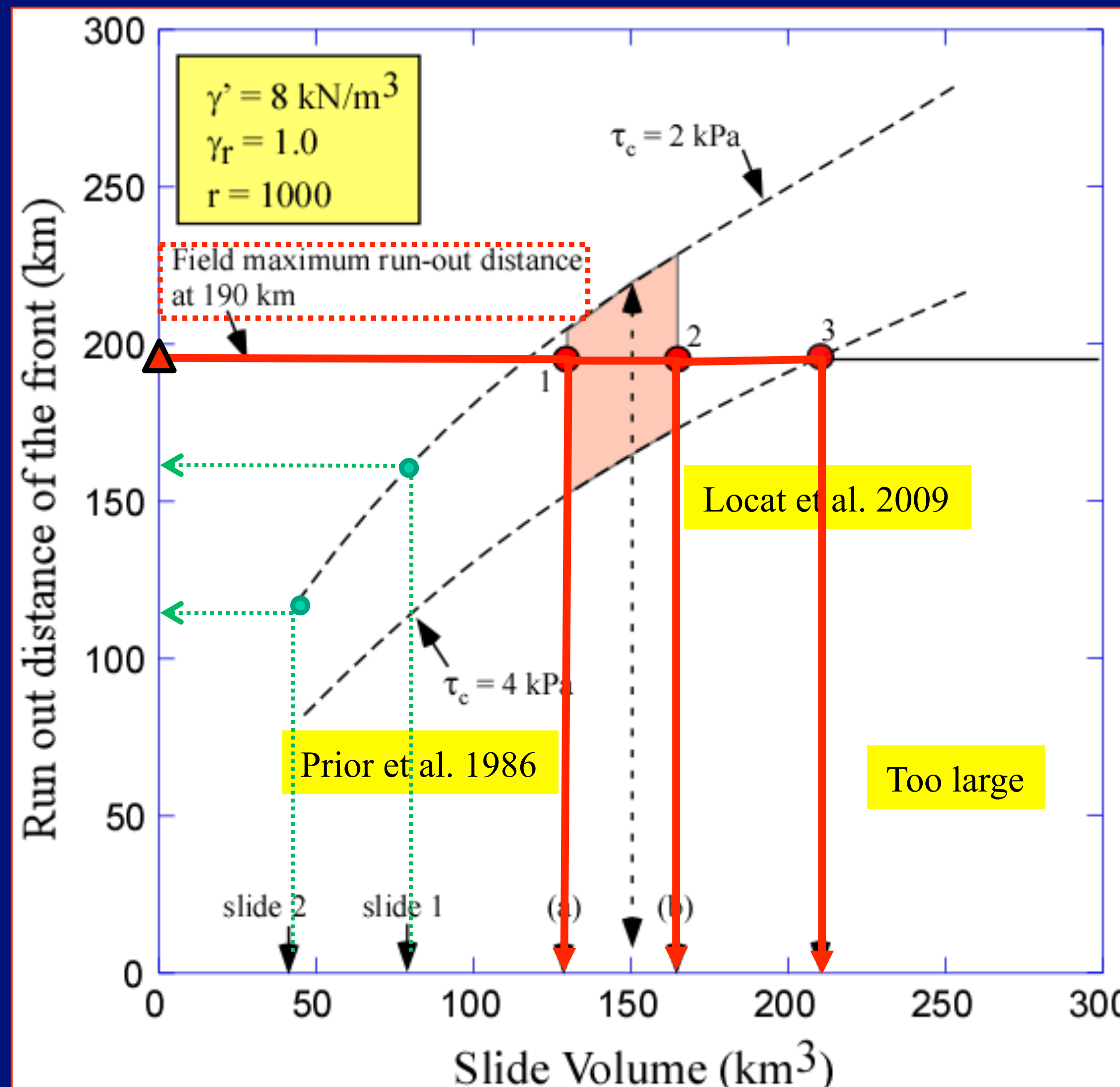


(a) (b)

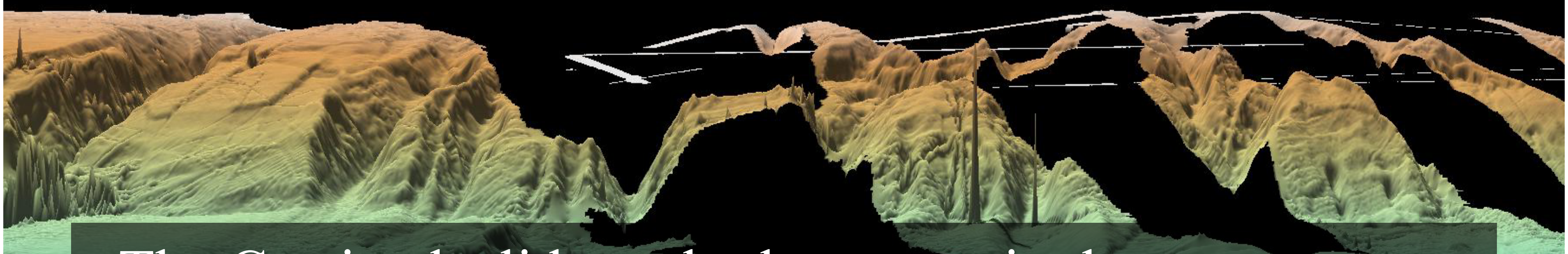
Initial acceleration may be unrealistic because as it assumes the material is already remoulded

Did the slide took place as a single event ?

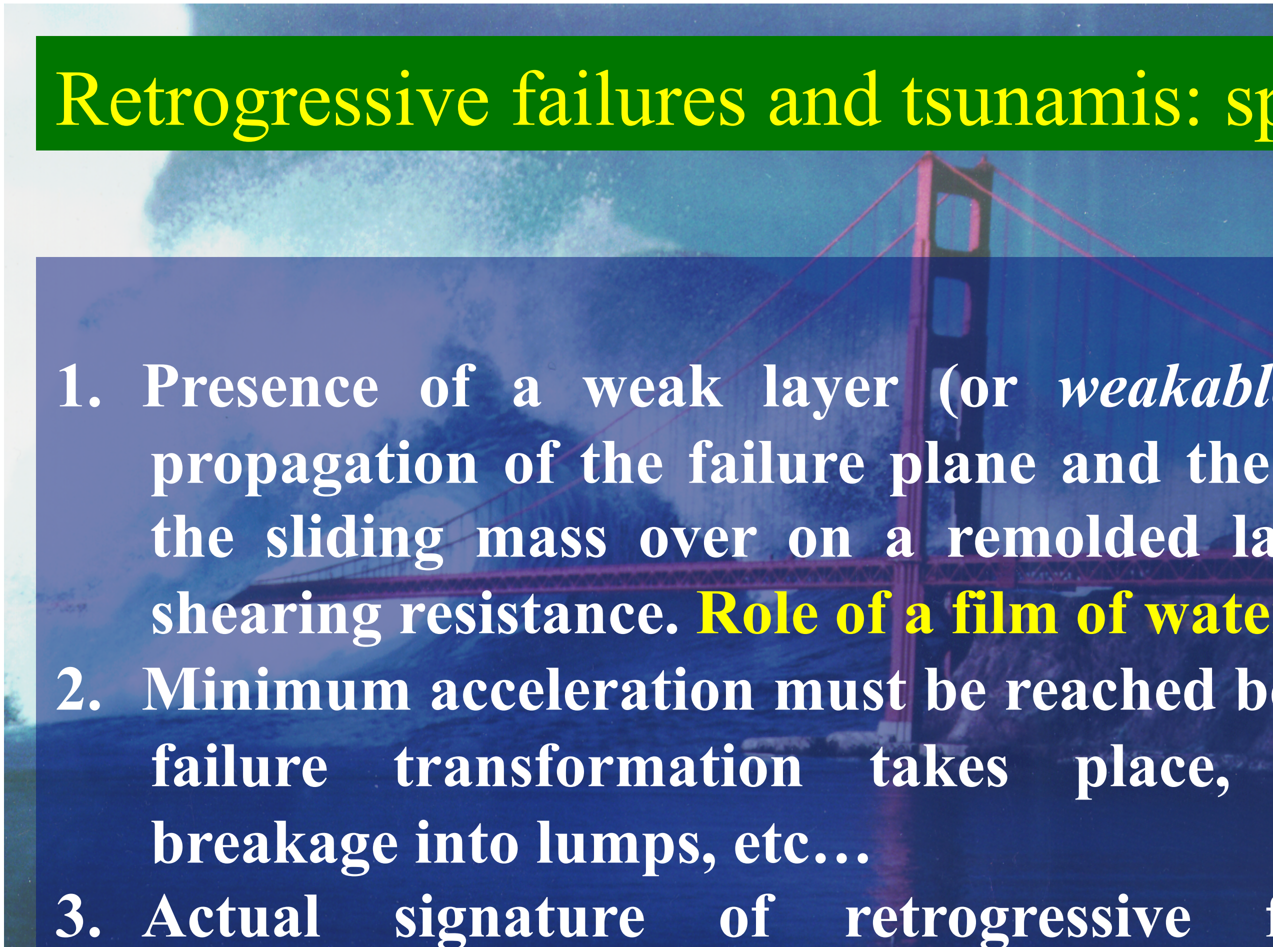
Initial volume and run-out distance for two values of the yield strength. Volume at (a) is from Prior et al. (1986) and his taken at 128 km³. Slide 1, and volume (b) is from our computation at 165 km³. Slide 1 and slide 2 are from models shown before. Field maximum run out is taken from field at 190 km.



Comments on the Currituck slide



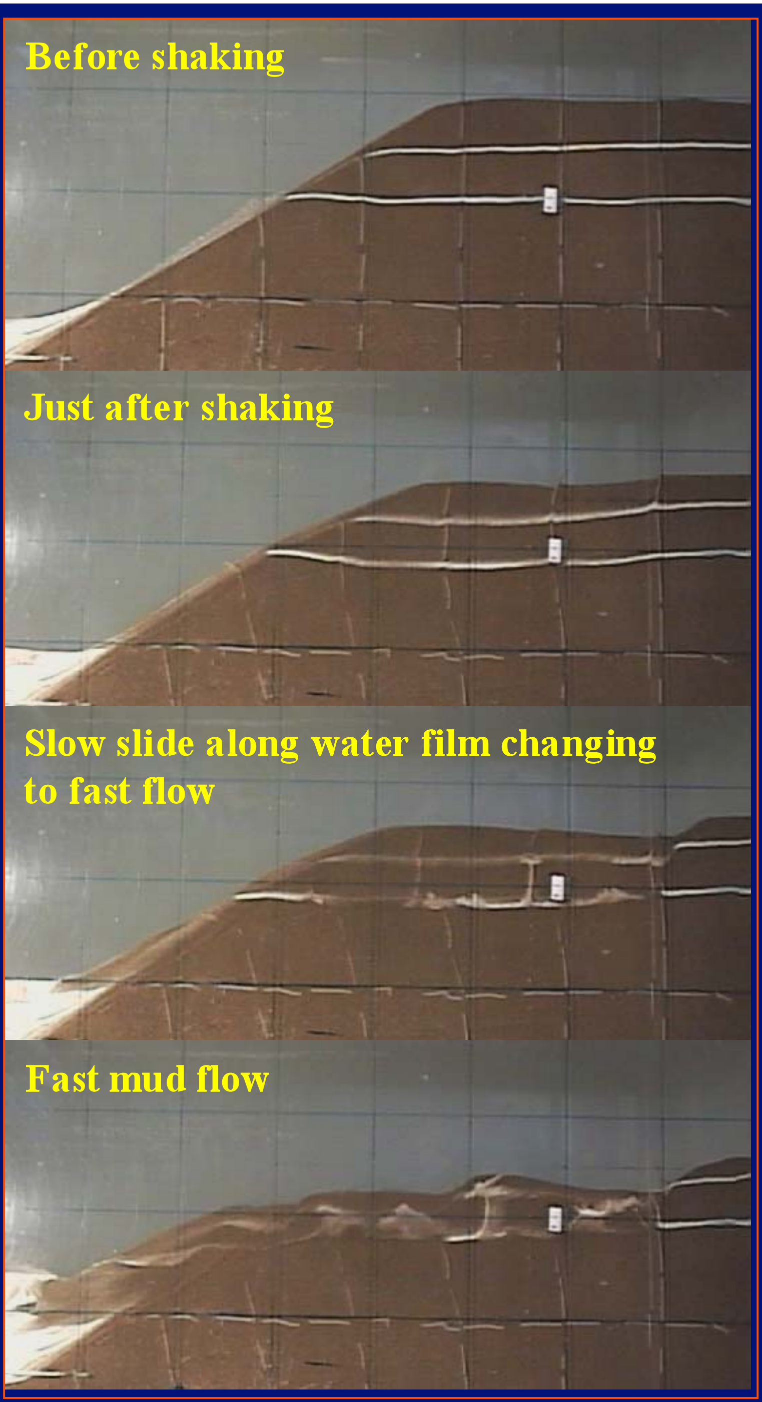
- The Currituck slide took place as a single event.
- It involved a volume of sediment between 150 km^3 and 165 km^3.
- The mobilized yield strength was of the order of 2000 to 4000 Pa. (still may involved some water intake)
- It was triggered by a catastrophic event that must have required a sudden increase in pore pressure, likely due to an earthquake or a process rapidly generating a failure over a large surface.



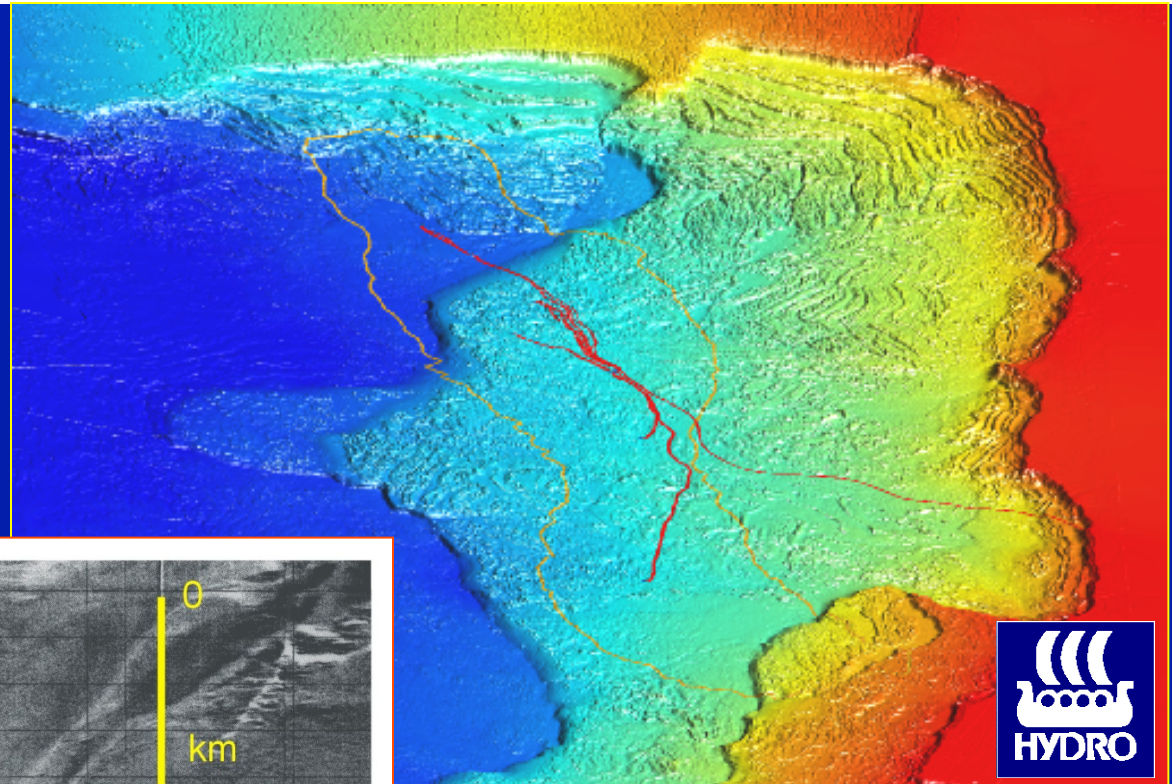
Retrogressive failures and tsunamis: special conditions:

1. **Presence of a weak layer (or *weakable*) ensuring a rapid propagation of the failure plane and the bulk mobilization of the sliding mass over on a remolded layer with a very low shearing resistance. Role of a film of water ?**
2. **Minimum acceleration must be reached before significant post-failure transformation takes place, e.g. desintegration, breakage into lumps, etc…**
3. **Actual signature of retrogressive failure are mostly concentrated near the final escarpment with little knowledge of the slide dynamics in the lower starting zone.**
4. **Any phase of a retrogressive failure can generate a tsunami, as long as a significant volume of the sliding mass gains enough acceleration (everything else being constant)**

Rapid development of a failure plane by the formation of a film of water at the hydraulic interface

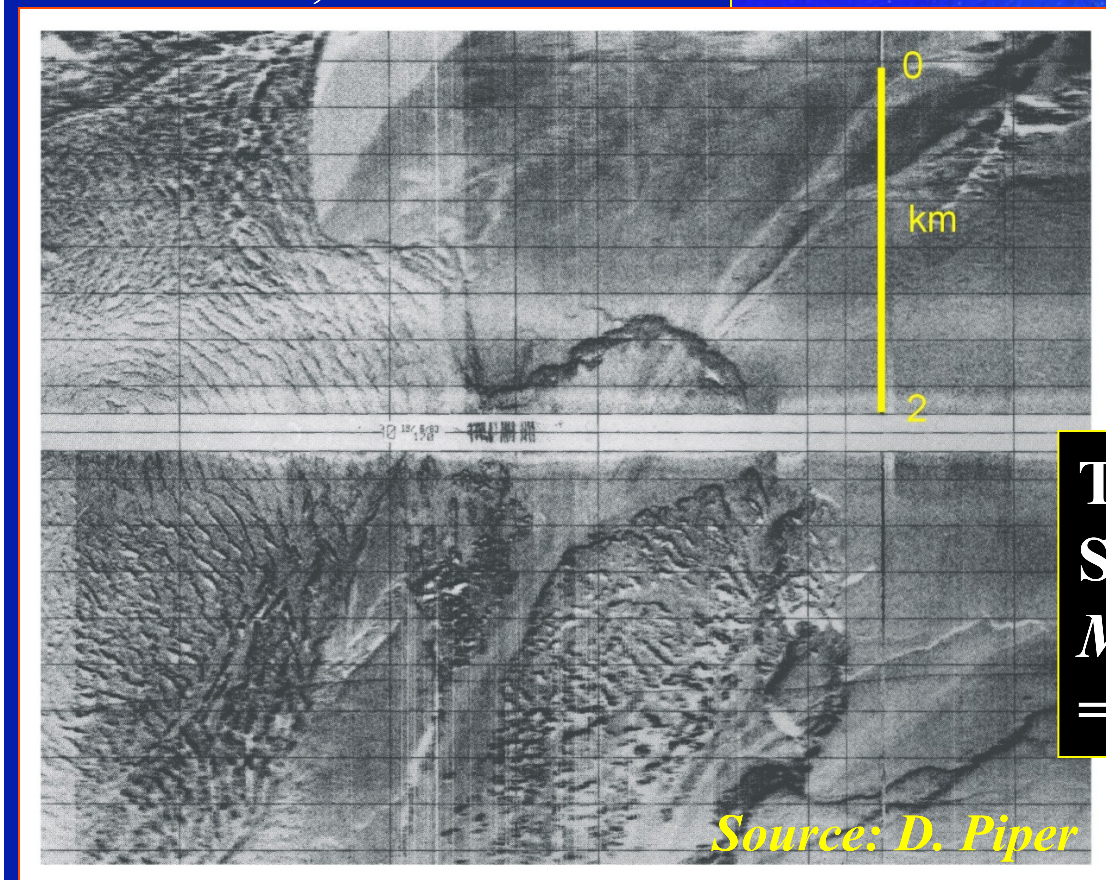


Which phase triggered the tsunami?



Storegga, 8200 yBP

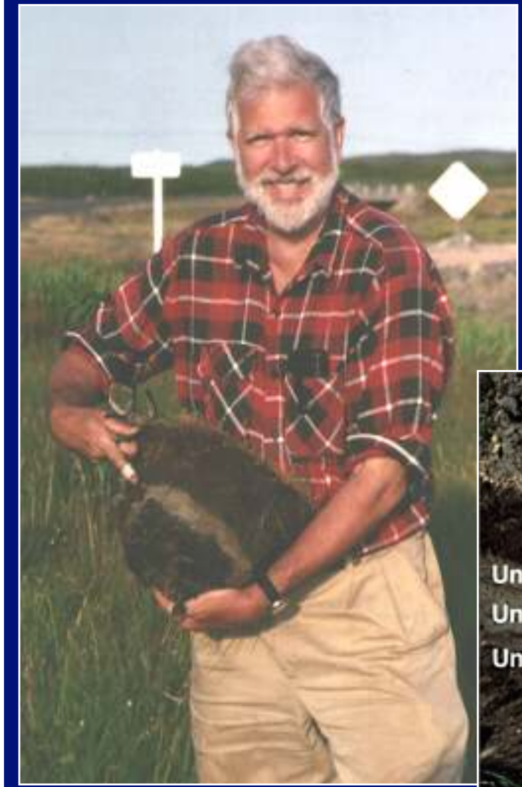
Grand Banks, 1929



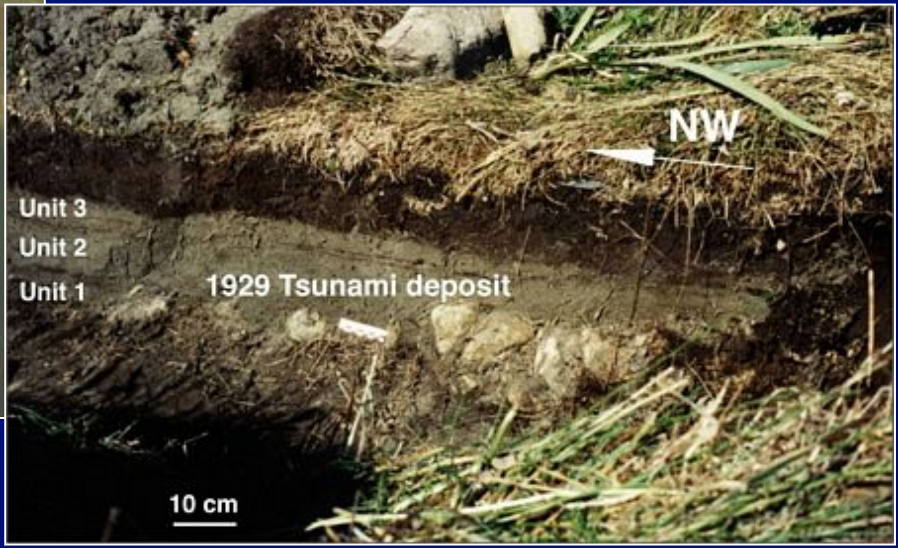
Source: D. Piper

Trigger: earthquake
Storegga: V = 2.3 km^3
M = ~ 7.2, Grand Banks: V = ~100 km^3

Comments on: Earthquakes and tsunamigenic slides



Allan Ruffmann



Photographs of the 1929 tsunami deposit (Tuttle et al., 2004).

Simulation du Tsunami du glissement des Grands Bancs slide (1929)
par B. Bornhold (Uvic) – COSTA-Canada

1929 Grand Banks earthquake and tsunami, 1929

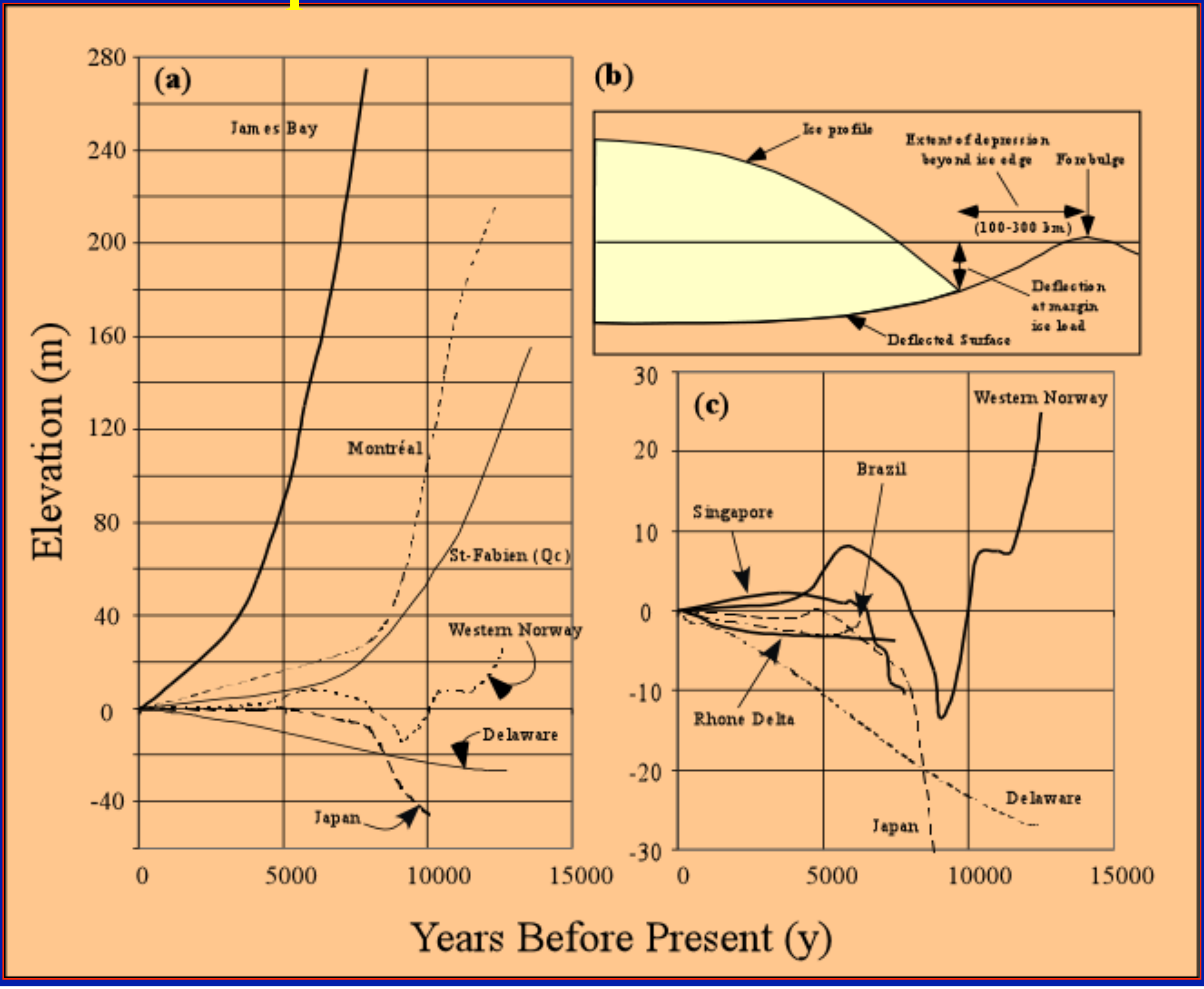
A proposal:

Already as part of the COSTA (2000-2003) project there were discussions to initiate an international study of the Grand Banks slide and tsunami with great interest from Norway, Spain and Canada, and I know of more recent interest. I think that in the light of the Japan disaster, this should consider even more seriously. We must remember that this is the most significant tsunamigenic landslide hitting the west coats in historical time.

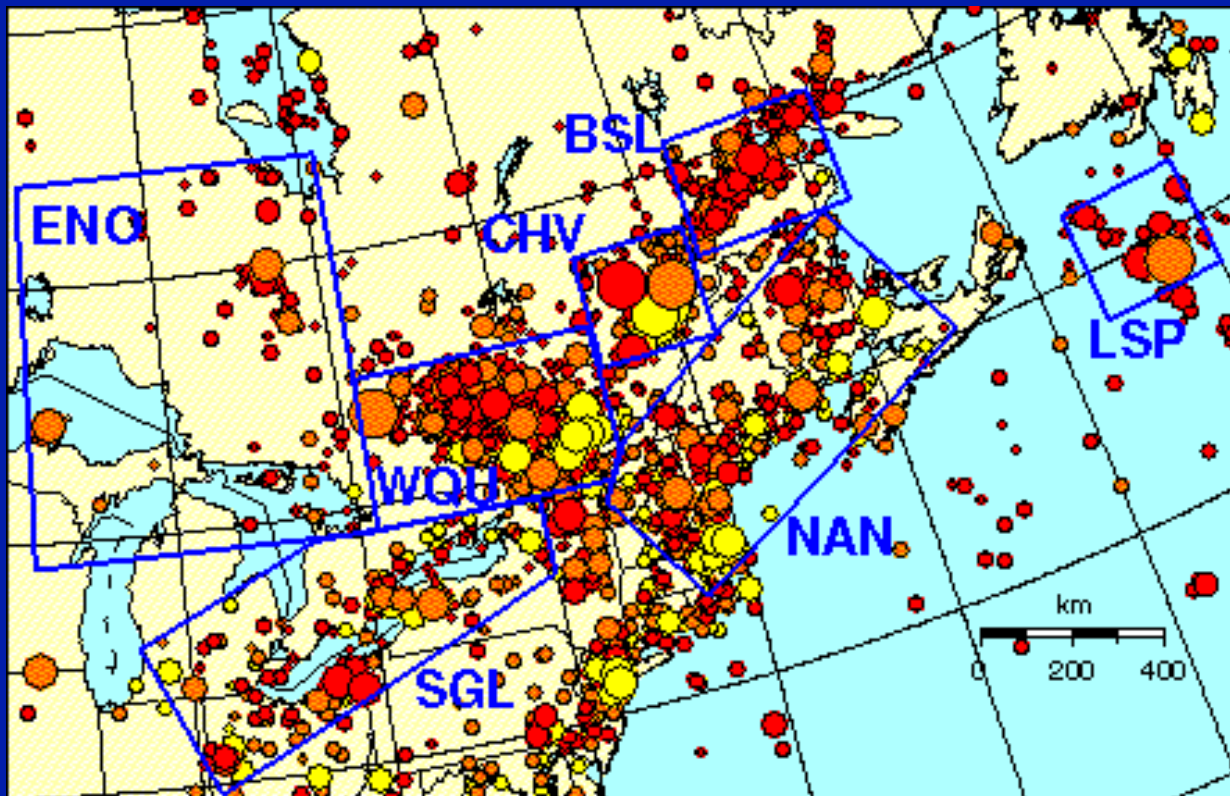
An interesting question:

How about the remaining strong earthquake potential in glaciated areas ?

Earthquake Risks in Glaciated Areas



Historical Seismicity on the American North Atlantic Seaboard



Historical Seismicity

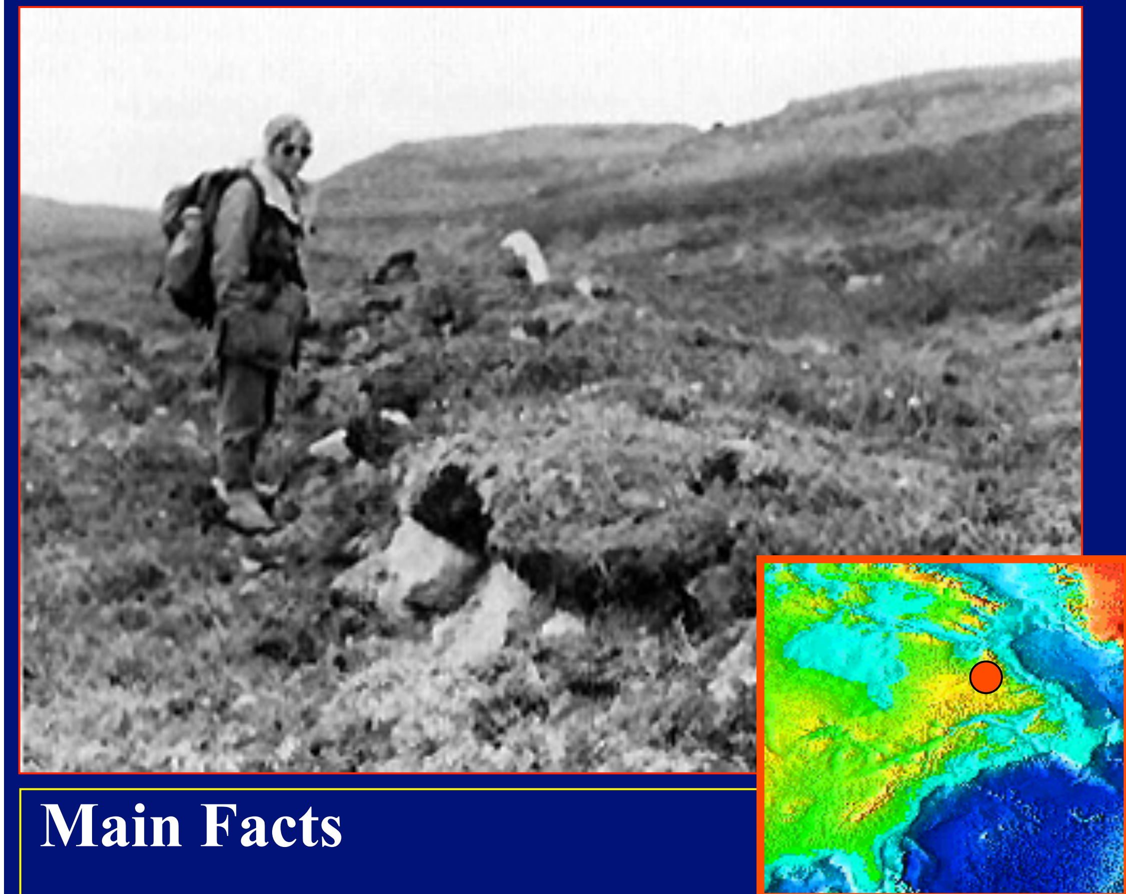
Yellow: < 1900 Orange: 1900 - 1964 Red: 1965-2001

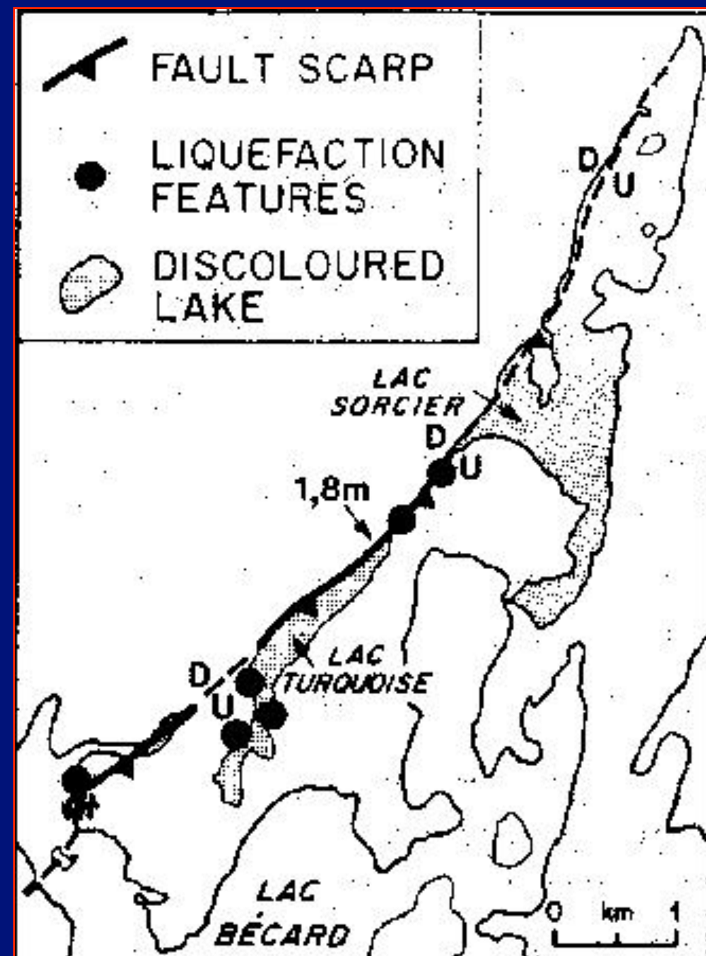
Uncertainty

+/- 50km +/- 25km +/- 10km

$2.5 \leq M < 3.0$ $M \geq 3.0$ $M \geq 4.0$ $M \geq 5.0$ $M \geq 6.0$

Ungava, Québec, Earthquake of 1989





Main Facts

8.5 km of surface faulting,

Maximum throw l.8 m on a thrust fault

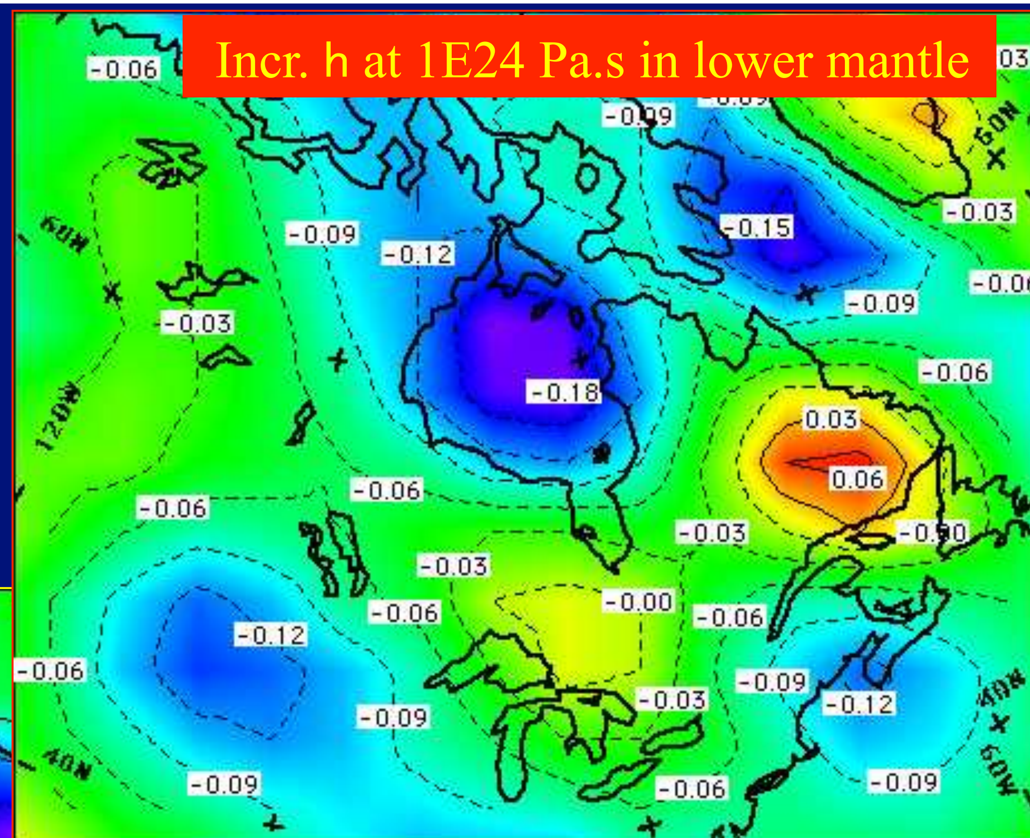
Magnitude 6.3 Ms

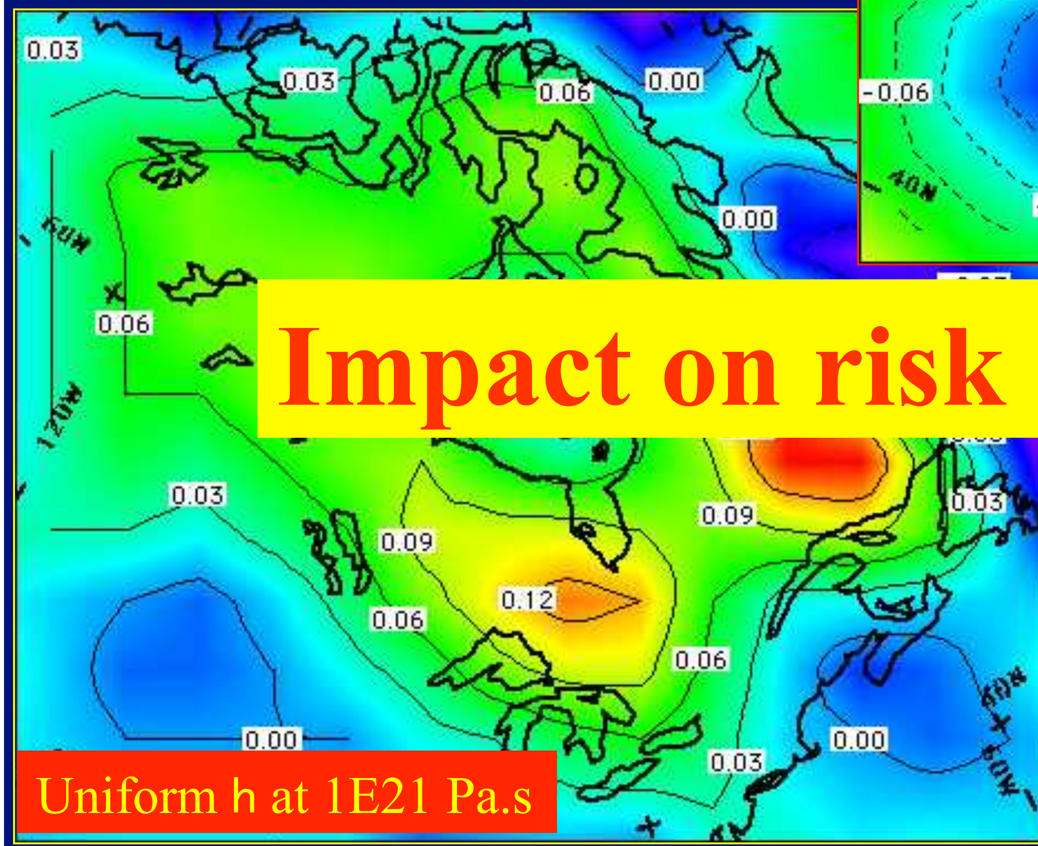
Hypocentre in Canadian Shield

Source: John Adams, GSC

Earthquake Risks

Will earthquake activities (frequency and magnitude) increase over the next few thousand years ?



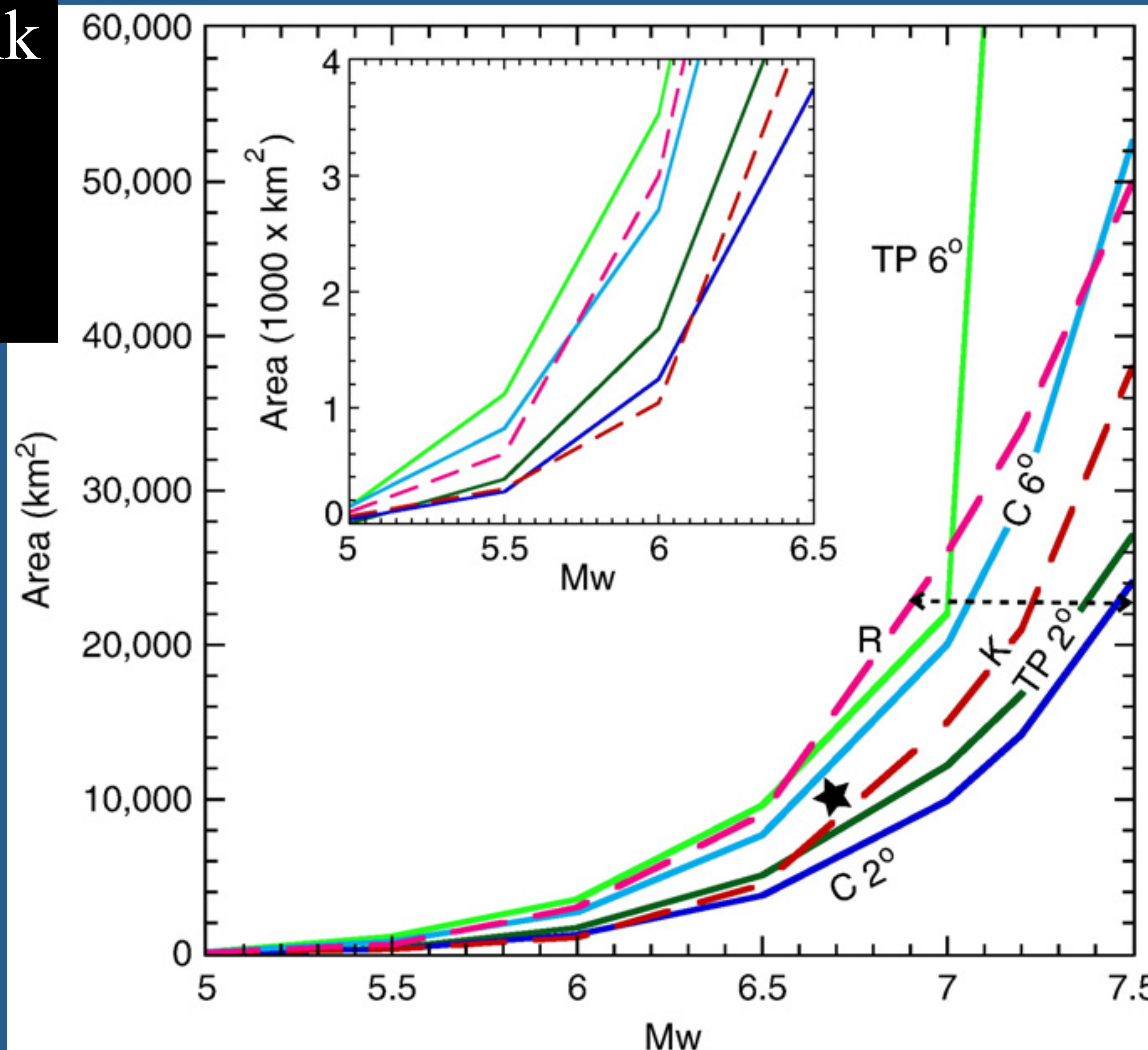


Impact on risk assessment ?

… that the amount of rebound stress available to trigger earthquake is decreasing with time. The intensity would depend on mantle viscosity to dissipate the stored strain energy due to glacio-isostasy

http://www.geo.ucalgary.ca/~wu/dFSMRate.html

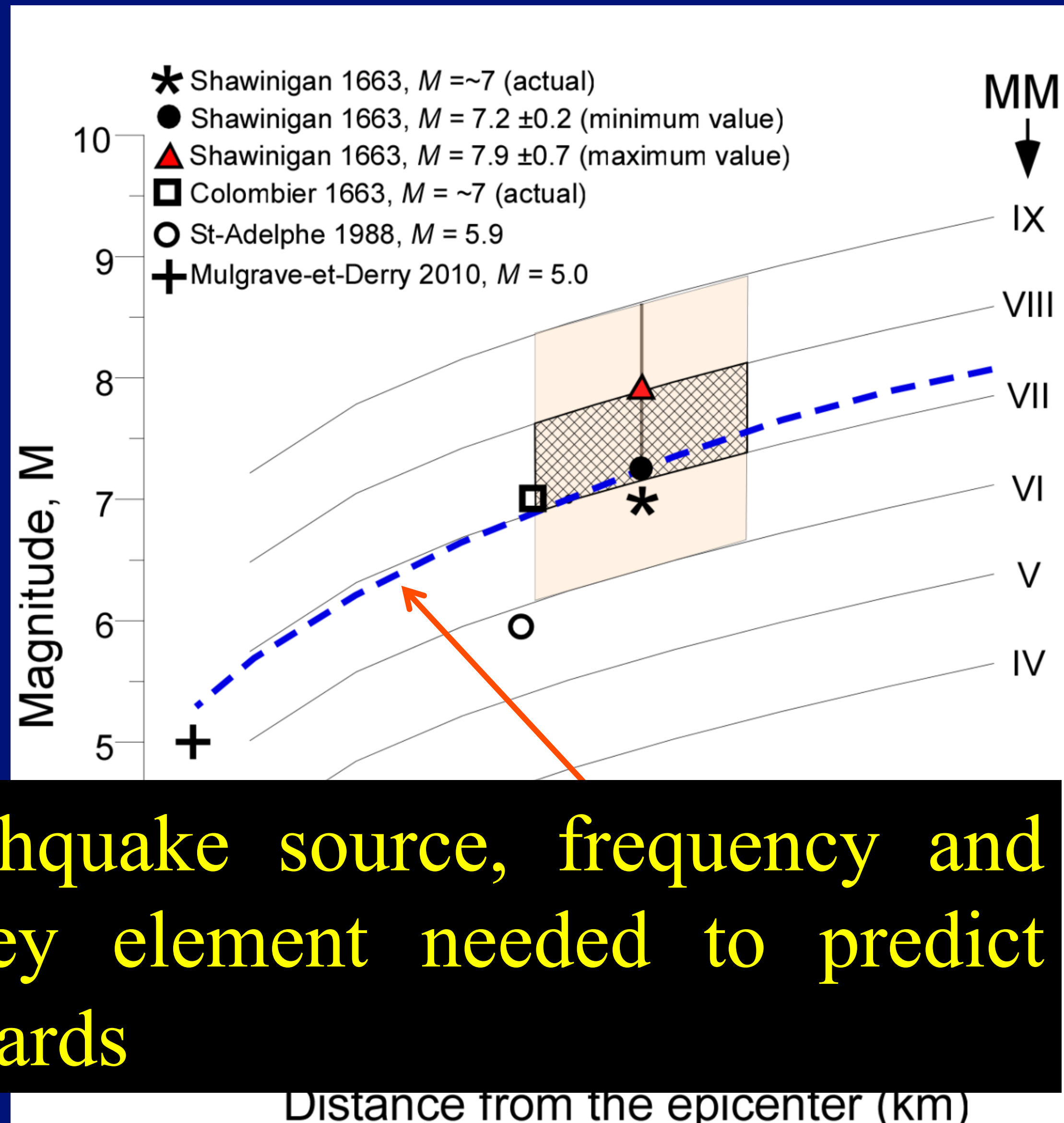
Possible to link area affected by a given earthquake



Ten Brink et al (2009)

Case of the 1663 Charlevoix Earthquake (M = 7.8 ±0.6)

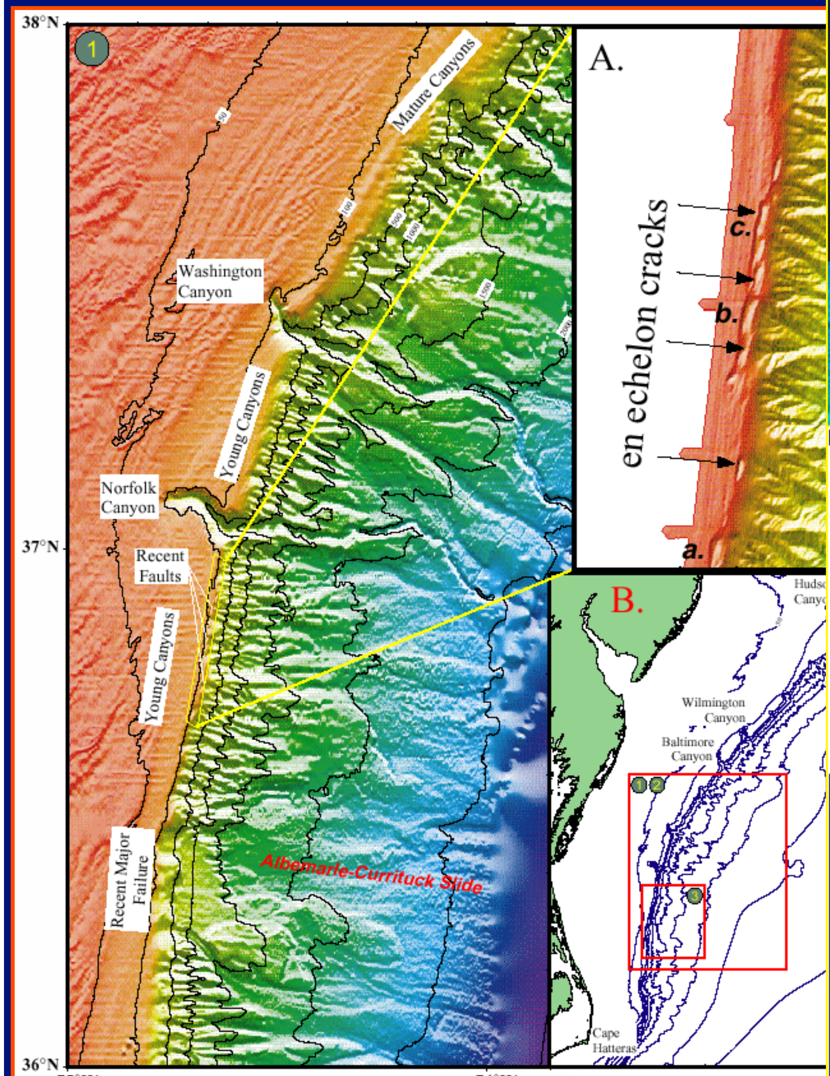
Earthquake magnitude, intensity and distance using the model of Bakun and Hopper (2004) for Eastern North America.



Understanding earthquake source, frequency and magnitude is a key element needed to predict submarine slide hazards

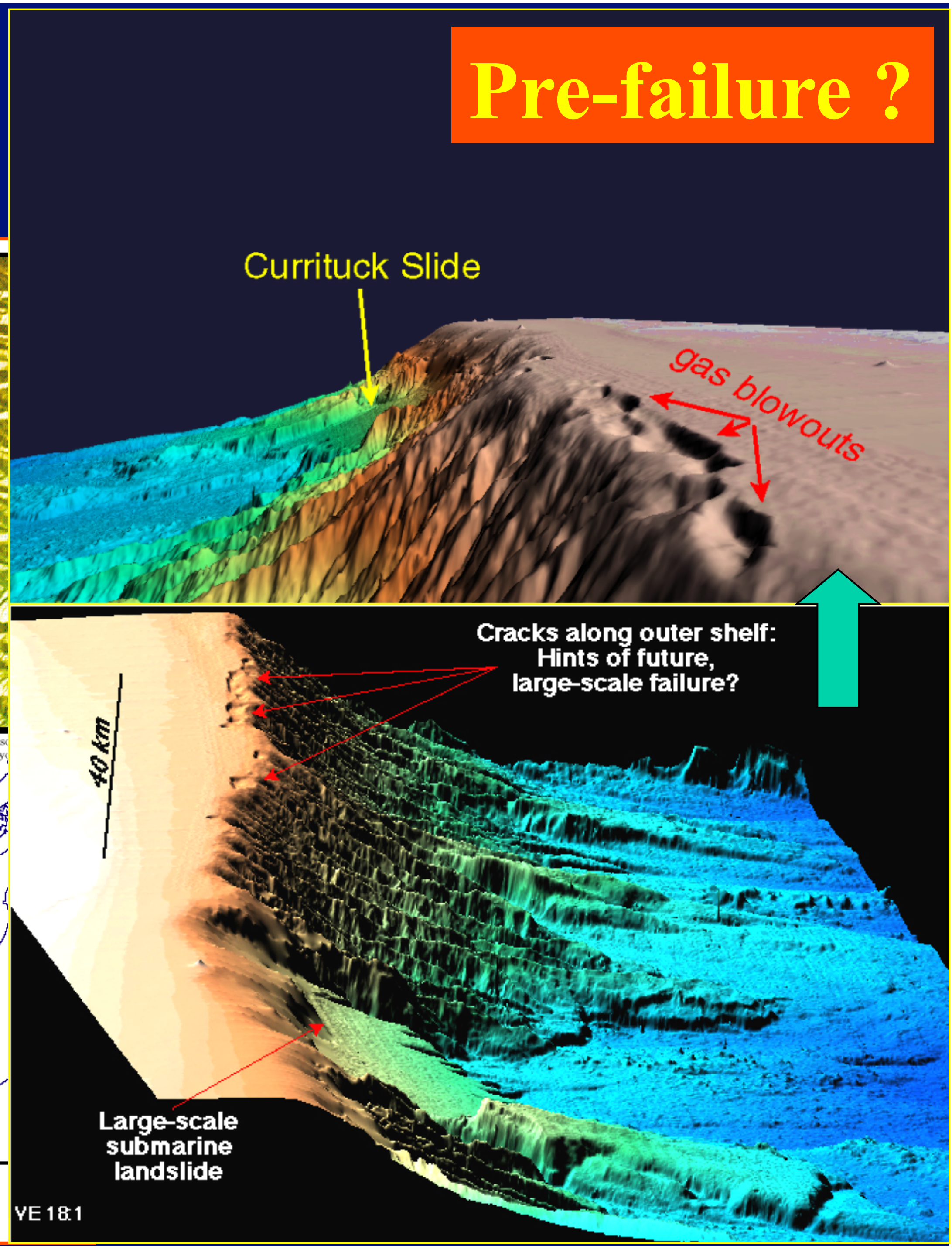
Locat 2011

Virginia/North Carolina Gas Blowouts ?

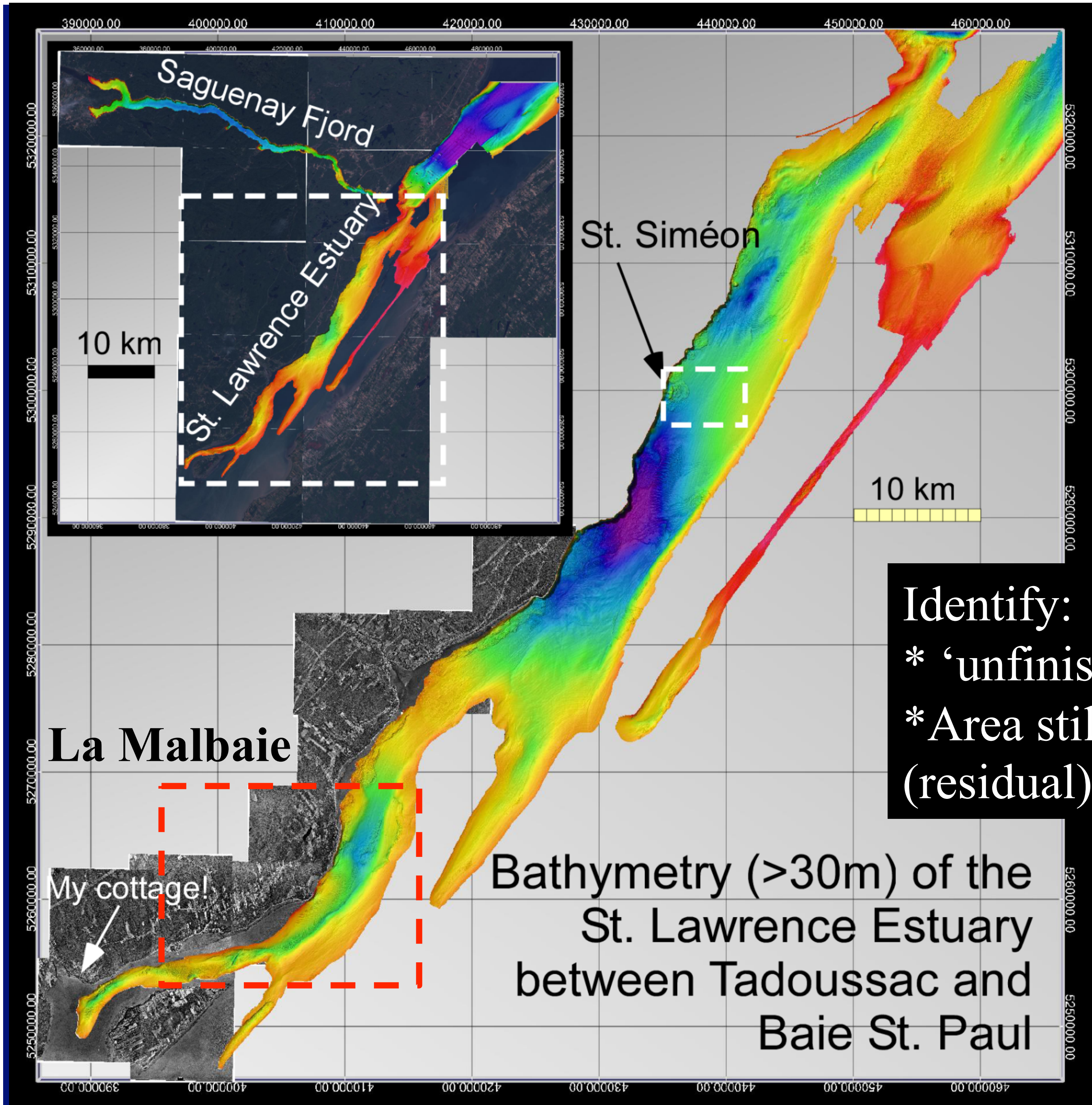


Geology; May 2000; v. 28; no. 5; p. 407–410;

Source: N. Driscoll

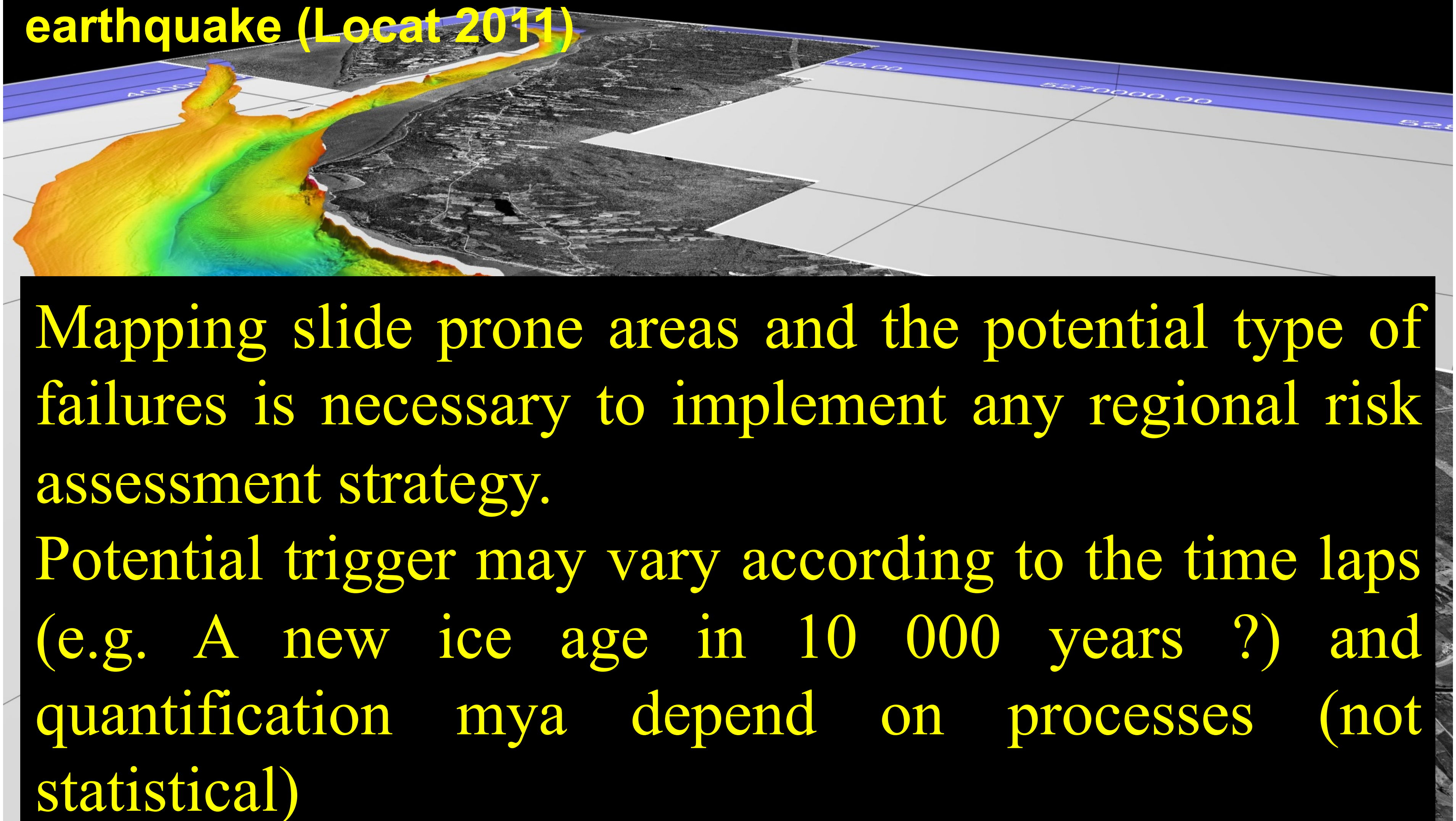


Mapping and dating submarine landslides an evaluating residuals



Identify:
* ‘unfinished’ slides
*Area still prone to sliding (residual)

Submarine landslides along Charlevoix coast near La Malbaie likely caused by the Charlevoix 1663 *M* =7.8±0.6 earthquake (Locat 2011)



Mapping slide prone areas and the potential type of failures is necessary to implement any regional risk assessment strategy.

Potential trigger may vary according to the time laps (e.g. A new ice age in 10 000 years ?) and quantification mya depend on processes (not statistical)

Concluding remarks

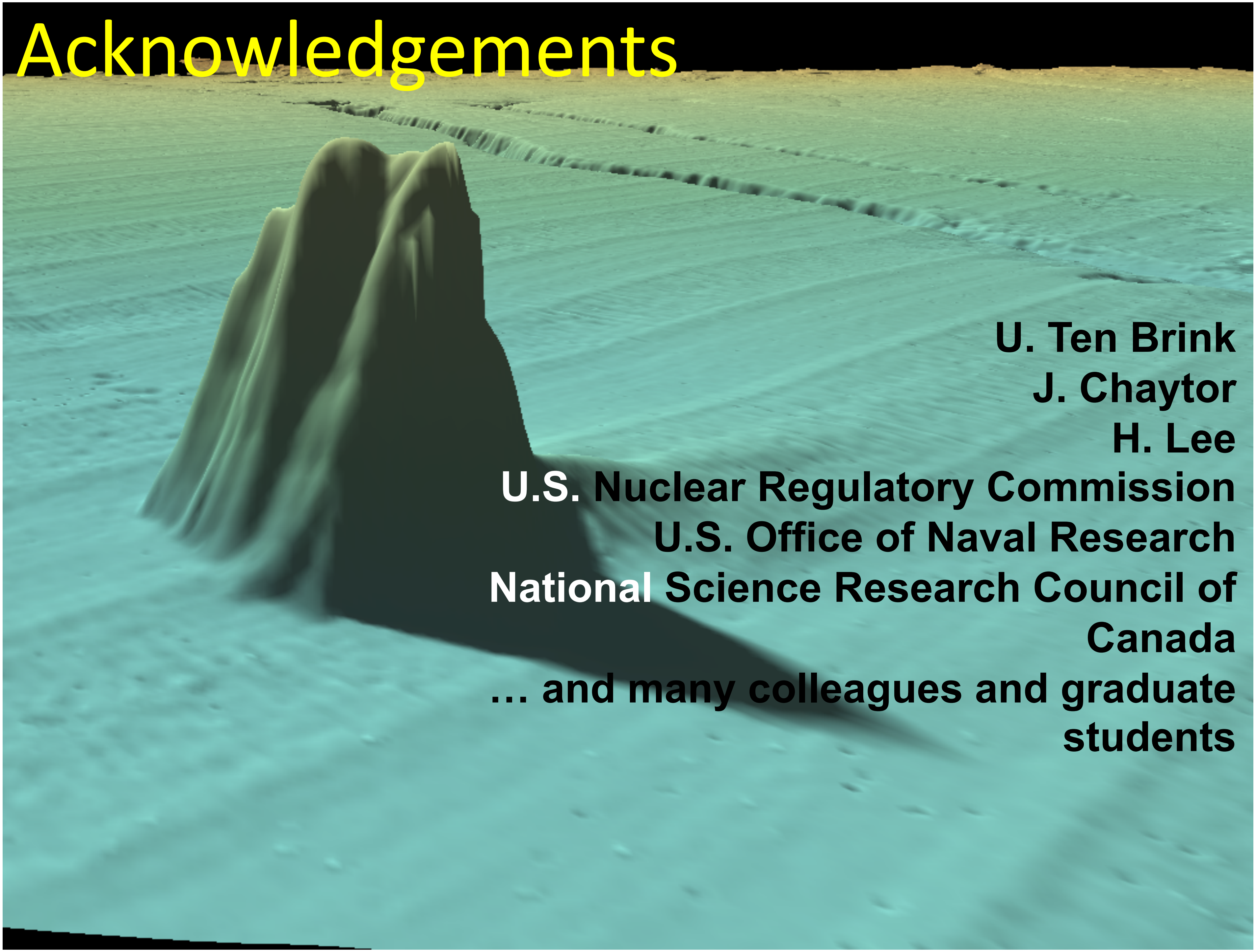
Critical geomechanical properties of tsunamigenic failures are:

- **Strength of material (drained or undrained): in situ measurements may be essential**
- **Sensitivity of a weak layer**
- **Deformability and initial rate process (desintegration)**
- **Structure (rocks)**

Limits:

- **Development of spread failure criteria still ungoing (A. Locat)**
- **Acceleration still is difficult to predict correctly: Newer approaches using deformation models may help understand the transition between failure and post-failure**
- **Mapping areas prone to failure and potential triggers**
- **How about easy access to 3D seismics**

Acknowledgements



U. Ten Brink

J. Chaytor

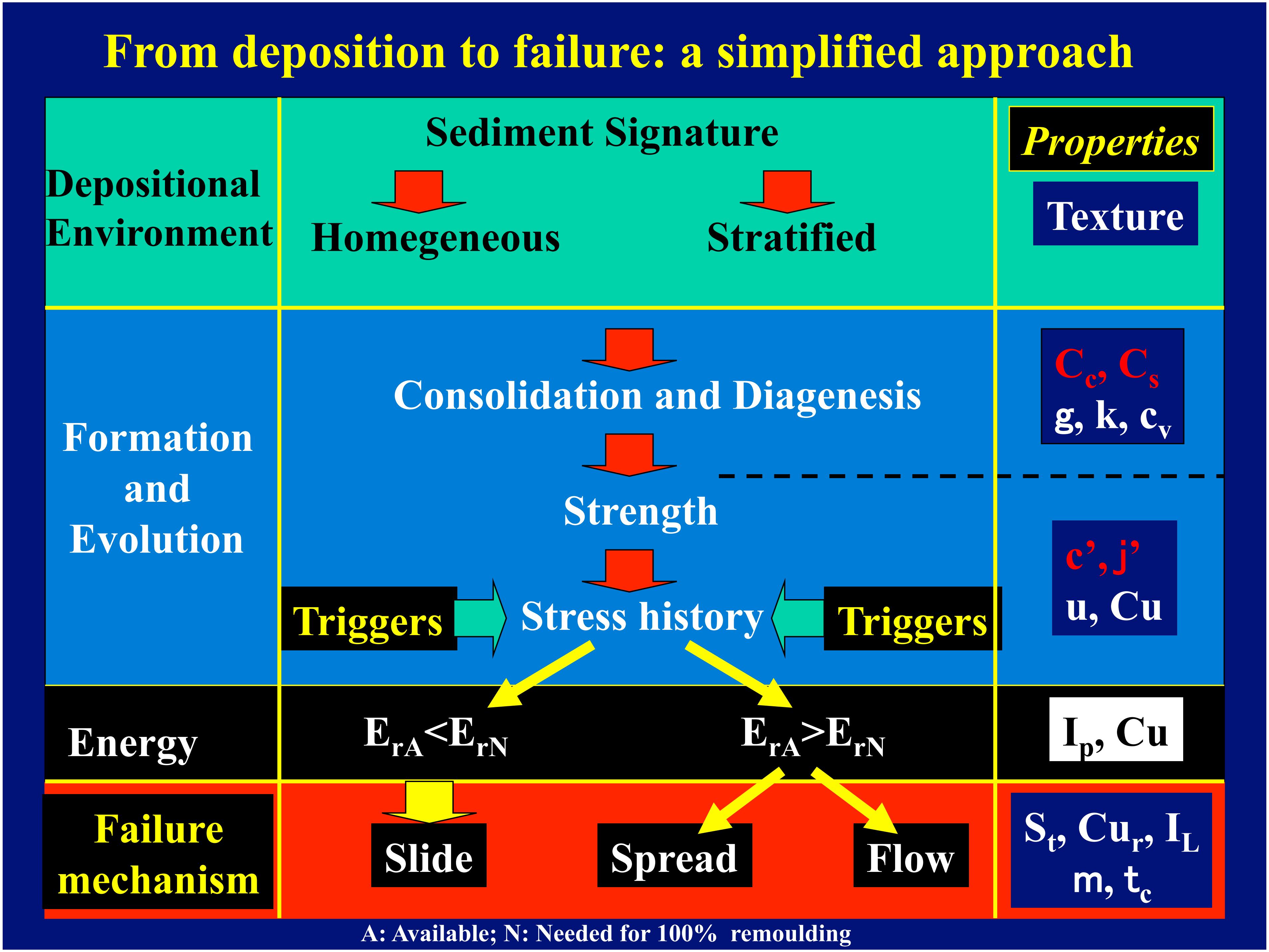
H. Lee

U.S. Nuclear Regulatory Commission

U.S. Office of Naval Research

National Science Research Council of Canada

… and many colleagues and graduate students


From deposition to failure: a simplified approach
Sediment Signature
Properties
Depositional Environment
Homegeneous
Stratified
Texture
Formation and Evolution
Consolidation and Diagenesis
C_c, C_s
g, k, c_v
Strength
c', j'
u, Cu
Triggers
Stress history
Triggers
Energy
$E_{rA} < E_{rN}$
$E_{rA} > E_{rN}$
I_p, Cu
Failure mechanism
Slide
Spread
Flow
S_t, Cu_r, I_L
m, t_c
A: Available; N: Needed for 100% remoulding